

CLAIMS

What is claimed is:

1. A solid-state device having a thin-film piezoelectric material forming a  
5 plurality of piezoelectric elements, a first set of the plurality of piezoelectric elements  
generating a force, and a second set of the plurality of piezoelectric elements generating  
an electrical signal in proportion to both the force and a rate of rotation of the solid-state  
device while rejecting spurious noise.
2. A solid-state rotational rate sensor device, comprising:  
10 a first set of piezoelectric elements;  
a second set of piezoelectric elements;  
wherein the first set of piezoelectric elements including a piezoelectric  
material and being actuated by an electrical signal, wherein when the electrical signal is  
applied on the piezoelectric material, the second set of piezoelectric elements senses a  
15 rotational rate of the solid-state rotational rate sensor device.
3. The solid-state rotational rate sensor device of claim 2, wherein the  
first and second sets of piezoelectric elements are configured on a thin-film piezoelectric  
material.
4. The solid-state rotational rate sensor device of claim 2, further  
20 comprising a third set of piezoelectric elements that sense a force generated by the first  
set of the piezoelectric elements.

5. The solid-state rotational rate sensor device of claim 4, wherein a signal sensed by at least one set of the second and third sets of piezoelectric elements is fed back to the first set of piezoelectric elements.

6. The solid-state rotational rate sensor device of claim 2, wherein the  
5 electrical signal applied on the first set of piezoelectric elements is variable to modify a mechanical resonant frequency of the solid-state rotational rate sensor device.

7. The solid-state rotational rate sensor device of claim 2, wherein the piezoelectric material of the first set of the piezoelectric elements includes conductive electrodes placed on approximately opposite sides such that application of the electrical  
10 signal to the conductive electrodes causes a longitudinal variation of the piezoelectric material.

8. The solid-state rotational rate sensor device of claim 2, wherein the piezoelectric material is a thin-film piezoelectric material with a thickness of less than 10 microns and includes conductive electrodes placed on approximately opposite sides such  
15 that application of the electrical signal to the conductive electrodes causes a longitudinal variation of the thin-film piezoelectric material.

9. The solid-state rotational rate sensor device of claim 2, wherein the piezoelectric material is a thin-film piezoelectric material comprising a family of Lead-Zirconate-Titanate (PZT) compounds.

20 10. The solid-state rotational rate sensor device of claim 2, wherein the solid-state device includes a semi-rigid member fixed along a first edge to a proof mass and fixed along a second edge to an outer base.

11. The solid-state rotational rate sensor device of claim 10, wherein the semi-rigid support comprises a tuning fork.

12. The solid-state rotational rate sensor device of claim 10, wherein the semi-rigid support comprises a vibrating cup.

5 13. The solid-state rotational rate sensor device of claim 10, wherein the semi-rigid support comprises a comb structure.

14. The solid-state rotational rate sensor device of claim 10, wherein the semi-rigid support comprises an annular ring.

15. A method of sensing a rotational rate of a solid-state device formed by a plurality of thin-film piezoelectric elements having a first set of piezoelectric elements, a second set of piezoelectric elements, and a third set of piezoelectric elements, comprising the steps of:

actuating the first set of piezoelectric elements by a first electrical signal;

and

15 sensing a rotational rate by the second and third sets of piezoelectric elements while rejecting spurious noise.

16. The method of claim 15, further comprising the steps of generating a second electrical signal by the second set of piezoelectric elements proportional to a mechanical force along a first direction, and generating a third electrical signal by the third piezoelectric elements proportional to the mechanical force along a second direction, wherein the second direction is orthogonal to the first direction, and wherein phase of the third electrical signal shifts relative to the second electrical signal in

response to rotation movement of the solid-state device around a third direction, and the third direction is orthogonal to both the first direction and the second direction.

17. The method of claim 15, further comprising the steps of connecting the second and third electrical signals to a phase-shift detection circuit, and generating an  
5 electrical output signal in proportion to a shift of the phase.

18. A rotational rate sensor, comprising:  
a proof mass;  
a first piezoelectric element for generating a force on the proof mass along  
a first direction by a first electrical signal;  
10 a second piezoelectric element for generating a second electrical signal in  
proportion to the force on the proof mass along the first direction;  
a third piezoelectric element for generating a third electrical signal in  
proportion to the force on the proof mass along a second direction; and  
an electrical circuit connected to the first piezoelectric element for  
15 applying the first electrical signal.

19. The rotational rate sensor of claim 18, further comprising a phase shift detection circuit that generates an electric output signal in proportion to a phase shift between the second and third electrical signals.

20. The rotational rate sensor of claim 18, further comprising a feedback  
20 circuit for feeding back a signal sensed by at least one set of the second and third sets of  
the piezoelectric elements.